

**TECHNICAL MEMORANDUM**

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## **Introduction**

### **Background**

The groundwater of the Glendale South Operable Unit (OU) is contaminated by volatile organic compounds, mainly trichloroethene and tetrachloroethene. James M. Montgomery, Inc. (JMM) and the Los Angeles Department of Water and Power (LADWP) conducted a feasibility study to evaluate alternatives for remediation of the groundwater. The remedial action includes groundwater extraction at 2,000 gallons per minute (gpm), treatment, and delivery of the treated water to the LADWP water system or other final use [1]. The treatment technologies for the removal of volatile organic compounds have been evaluated and summarized in the feasibility study report. However, in some of the recent groundwater samples, a total chromium concentration as high as 1.2 milligram per liter (mg/l) were detected in a single monitoring well. This concentration level exceeds the maximum contamination level (MCL) for drinking water in the State of California, total chromium of 0.05 mg/l.

Chromium occurs in aqueous systems as both the trivalent (Cr[III]) and hexavalent (Cr[VI]) form, as chromate ( $\text{CrO}_4^{-2}$ ) and dichromate ( $\text{Cr}_2\text{O}_7^{-2}$ ). Cr(VI) is not commonly found in nature. Industrial sources are usually suspected when Cr(VI) is detected. The sources of chromium contamination are most likely related to chromic acid bath and rinse water used in metal cleaning, metal-plating, electroplating, and leather tanning operations.

Cr(III) is nutritionally essential and nontoxic. The estimated safe and adequate intake is 0.05 mg to 0.2 mg per day. Cr(VI) is toxic, producing liver and kidney damage, internal hemorrhage, and respiratory disorders. Cr(VI) also has been shown to cause cancer in humans and animals through inhalation exposure, but not through ingestion. The EPA classifies chromium as a human carcinogen (group A).

Because only total chromium is monitored in the groundwater of Glendale South Operable Unit, no speciation information of chromium is available. Because Cr(VI) could be soluble under these groundwater conditions and Cr(VI) is more toxic, we have assumed that the total measured chromium consists wholly of Cr(VI). The extent and significance of chromium contamination in the groundwater is not yet fully understood because of limited data. EPA requested CH2M HILL to perform a treatment technology evaluation for chromium removal assuming that all chromium detected was Cr(VI). Treatment for chromium removal may not be required when the extent of contamination is better defined in the future. EPA desired this information in order to evaluate the advantages and disadvantages of the different technologies for chromium removal.

## **Objective**

The objective of this Technology Memorandum (TM) is to evaluate chromium removal technologies that can achieve the treatment goal and protect public health. The following tasks were performed to achieve the objective:

- Treatment Technology Screening. Various physical, chemical, and biological treatment technologies were screened. The focus of the screening was to select proven and applicable technologies for more detailed treatment evaluations.
- Treatment Technology Evaluations. More detailed technology evaluations were performed for viable treatment technologies primarily based on EPA's nine-criteria analysis procedure.

## **Treatment Technology Screening**

Chromium contamination often exists in the waste streams of industries such as electroplating, cooling water blowdown, leather tanning, etc. Technologies that are currently used or studied in the industries to remove chromium include:

- Alum coagulation, sedimentation, mixed media filtration, and carbon adsorption
- Chemical reduction and precipitation
- Electrochemical reduction and precipitation
- Reverse osmosis
- Electrodialysis
- Ion exchange
- Direct precipitation
- Biological treatment

Most of these treatment technologies are proven effective to treat low-flow, high concentration industrial wastewater and may not be cost effective to treat the high-flow, low

concentration as in the groundwater of Glendale South OU. Also, these technologies usually only required treating wastewater to meet the effluent discharge requirement, and may not be able to meet more stringent drinking water regulations. The purpose of technology screening is to identify technologies applicable to Glendale groundwater for further evaluation.

### **Alum Coagulation, Sedimentation, Filtration, and Carbon Adsorption**

This process train is commonly applied in water treatment for particulate and organic removal. Alum is added to water and coagulates with particles and organic contaminants to form alum flocs. Alum flocs will then be removed by sedimentation and filtration. Carbon adsorption can further remove dissolved organic contaminants. The removal of chromium in water is dependent on whether chromium is associated with particulate or organic contaminants. Chromium will be removed together with particulate and organic contaminants if chromium is adsorbed on particulate or chelated by organic material.

Direct alum coagulation, sedimentation, mixed media filtration, and carbon adsorption has been reported to reduce Cr(VI) from 0.7 to 0.018 mg/l. Coagulation and filtration alone removed 61 to 64 percent of the chromium [2]. In one pilot study of metal removal from municipal effluent, initial hexavalent chromium levels of 0.09 to 0.19 mg/l were reduced to 0.04 mg/l or less by activated carbon adsorption. The average effluent concentration reported was 0.017 mg/l [3]. It appears that activated carbon may not be equally effective at high chromate levels [4]. The Cr(VI) removal efficiency ranged from 99 percent at pH 6 to 20 percent at pH 8 [5]. The Glendale groundwater, average pH of 7.5, may require pH adjustment (lower pH to around 6) for effective removal of Cr(VI). The chromium-laden carbon bed could not be regenerated to provide subsequent chrome removal.

There is no full-scale application of this process to remove chromium making it impossible to evaluate its effectiveness. Therefore, this technology will not be considered further in the future evaluation.

### **Chemical Reduction and Precipitation**

Reduction of hexavalent chromium to a valence state of plus three, and subsequent hydroxide precipitation of the trivalent chromic ion, is the most commonly applied method of hexavalent chromium removal. The reducing agents that are frequently used for this process are either sulfur-based (sulfur dioxide, bisulfite, metabisulfite, etc.) or iron-based (scrap iron, ferrous sulfate).

#### ***Chemical Reduction with Sulfur-based Reducing Agents***

The standard reduction treatment technique is to lower the waste stream pH to 2.0 to 3.0 with sulfuric acid, and convert the hexavalent chromium to trivalent chromium with a chemical reducing agent such as sulfur dioxide, sodium bisulfite, metabisulfite, or hydrosulfite. The pH of the water is then raised to 7.5 to 9 and trivalent chromium is removed by hydroxide precipitation. The reduction rate of hexavalent to trivalent chromium is not instantaneous,

and the amount of residual non-reduced hexavalent chromium depends on the allowed time of reaction, pH of the reaction mixture, the quantity of reducing agent that is present, and chromium concentration.

Sulfur dioxide is the most popular reducing agent used in treatment of chromium, primarily because it is relatively inexpensive. Hexavalent chromium levels of 0.01 mg/l have been achieved by reduction at pH 2.5-4.0 [6]. Sulfuric acid and sulfur dioxide was used to reduce Cr (VI) from 8.75 mg/l to 0.01 to 0.03 mg/l in a cooling water blowdown application [7]. A fully automated continuous-flow chromate treatment system is available, which yields hexavalent chromium levels below 0.05 mg/l.

The advantages of this process are:

- Proven technology
- Less sludge production than iron-based reduction process

However, the major disadvantages are:

- Two pH adjustments are required. The flow rate for this project makes this technology difficult to impossible to implement.
- Leakage of sulfur dioxide or other sulfur-based reagents may produce unpleasant smell or even pose health hazard. This is undesirable in a heavily populated area.

This technology will not be considered further.

### **Chemical Reduction with Iron-Based Reducing Agent**

Many installations employ ferrous sulfate or ferrous chloride as a reducing agent for chromate reduction. Ferrous ion will reduce Cr(VI) to Cr(III); while the ferrous ion is oxidized to ferric ion. The Cr(III) and ferric ion will then co-precipitate at pH 7.5 or above. Ferrous ion has been reported to have the advantage over sulfur dioxide of effectiveness over a wide range of pH. However, it also has been reported that use of ferrous ion yields much greater quantities of sludge than are produced through use of sulfur dioxide or bisulfite. The added iron salt precipitation results in about three to four times the sludge volume produced by other reduction/precipitation alternatives [6]. A package treatment unit is available for this process [8].

As an alternative approach to reduce iron demand and resulting sludge production, metallic scrap iron has been used to reduce hexavalent chromium under acidic conditions. By direct conversion of metallic to ferric iron, chromium reduction would have a theoretical molar stoichiometric iron demand of 1:1 versus the theoretical 3:1 molar demand associated with ferrous iron as the reductant. Reduction kinetics depends on the initial chromium concentration, increased iron surface area, and pH. Mixing rate also influences the rate constant

[6]. However, scrap iron may contain other contaminants and, thus, is not suitable for a drinking water application.

The advantages of ferrous reduction are:

- Proven technology
- Package treatment unit available
- No need to adjust pH, only need to maintain pH at 7.5 to 8.0
- Simple equipment, low capital cost

The disadvantage of this process is the large quantity of sludge produced which will increase the sludge disposal cost. However, when the chromium concentration is low, as in the case of Glendale groundwater, the total amount of sludge produced may not be excessive for off-site disposal. The ferrous reduction process will be considered further in the future evaluation.

### **Electrochemical Reduction and Chemical Reduction**

This technology induces the reduction of Cr(VI) to Cr(III), not by addition of chemicals, but by employing an imposed DC electrical potential and consumable iron electrodes. Electric current applied to the electrodes results in the release of ferrous ions into solution. These ferrous ions then reduce the Cr(VI) to yield Cr(III) ions. The Cr(III) ions will then form hydroxide precipitate and settle out of water. This technology is best suited for the application to low-level of chromium contamination. There is a package treatment unit available for this process. It has been reported to achieve chromate reduction from 3.5 mg/l to below 0.05 mg/l in cooling-tower blowdown [9].

Conflicting results regarding the sludge production were reported. One source has reported a four fold increase in dry sludge solids as a result of the soluble iron released in the electrochemical reactions [10]. Another source claims excessive sludge is probably due to insufficient process control [11]. Since this technology is based on the same principles as that of iron reduction, the sludge produced should be similar in quantity.

The advantage of electrochemical reduction are:

- Proven technology, suitable to low concentration applications.
- Package treatment unit available.
- No need to adjust pH, only need to maintain pH between 7.5 and 8.0.
- Minimal chemical handling required.

The disadvantage of this process is the large quantity of sludge produced which will increase the sludge disposal cost. The electrochemical reduction process will be considered further in the future evaluation.

## **Ion Exchange**

The ion exchange process is reported to be economical for chromium recovery [6]. Anion exchange can be employed to remove hexavalent form of chromium (chromate and dichromate). When the anion exchange resin is exhausted, it is regenerated (usually with sodium hydroxide), and sodium chromate is eluted from the ion exchange resin. The eluted sodium chromate can be passed through a cation exchange resin to recover purified chromic acid at concentrations as high as 6 percent. If chromic acid is not recovered, the concentrated waste yielded by the resin regeneration process must be treated. This may be accomplished by reduction to trivalent chromium, followed by precipitation.

Both weakly basic and strongly basic anion exchanger have been used for chromate removal. The earliest ion exchange systems for chromate utilized weak-base resins. However, these have generally proved to be unstable because of the oxidizing conditions under which the exchanger operate. Strong-base gel-type resins also have been widely applied, but have experienced widespread fouling problems. More recently, weak-base macroporous resins have been used with success.

In the ion exchange system, water pH is a critical factor. At pH below 4, the oxidizing power of the chromic acid begins to attack the resin. At pH above 6, the ratio of chromate to dichromate in solution increases. Most anion exchange resins are less selective for dichromate, and early leakage of chromium occurs. Highly basic anion-exchange resins preferentially remove chromate at pH 4.5 to 5 before phosphate or sulfate.

After a year-long pilot plant test of ion-exchange treatment of cooling-tower blowdown containing 8 to 10.7 mg/l hexavalent chromium, Richardson et. al reported 0.0 to 0.09 mg/l hexavalent chromium, depending upon the period of operation between exchange resin regeneration [14].

Ion exchange is a proven method of treating chromium-bearing water. Although ion exchange has the disadvantages of high capital cost and operating complexity, it will be further evaluated to compare with more conventional reduction/precipitation treatment technology because ion exchange has the advantage of producing a relatively pure solution of chromic acid, sodium dichromate, or sodium chromate for potential reuse or sale.

## **Reverse Osmosis**

Reverse osmosis (RO) is used most often for desalting of water. RO uses pressurization of the feedwater and subsequent passage through a membrane as the means for removing impurities from the influent stream and concentrating them in the reject stream. RO processes often recover 75 to 85 percent of the feed water as a high-quality permeate stream and produce a large volume (15 to 20 percent) of waste stream (reject). The experience of applying RO for hexavalent chromium removal is limited. Waste stream from RO contains high concentration of Cr(VI) and requires further treatment with other technologies [6].

Polyetheramide membranes are reported to perform well for chromic acid concentration and recovery [12]. pH control is required to minimize acid hydrolysis of the reverse osmosis membrane. Some membranes are not suitable for solutions with high oxidation potential such as concentrated Cr(VI). A recent report indicates that TCE, which exists in the Glendale South OU groundwater, will negatively affect the performance of RO membranes in removing other constituents [13].

The membranes require careful operation and usually require expensive pretreatment to protect from scaling, oxidation, or premature failure. Since hexavalent chromium is a strong oxidant and membranes are sensitive to oxidation, close operator attention is necessary to prevent membrane damage. If fouling or scaling occurs, the membrane may need to be replaced if chemical cleaning is ineffective. Both water reuse and concentration of contaminants provided by membrane systems would be beneficial; however, RO cannot produce a stream that is concentrated enough for direct recovery of chromium.

In comparison with ion exchange, RO has a roughly equivalent treatment effectiveness but more expensive on capital, O&M, and waste disposal cost. Therefore, RO will not be considered further in the future evaluation.

### **Electrodialysis**

Electrodialysis (ED) employs the use of membranes which transport ions but not water across the membrane barrier. An electrical potential is applied across the membranes which causes ions to migrate toward either a cathode or anode depending on their charge. Ions are then concentrated on one side of the membrane, while a dilute solution is left on the other side. The concentrated stream typically requires further treatment or disposal.

The membranes used in ED require careful operation to protect the membrane from scaling, oxidation, or premature failure. If fouling or scaling occurs, the membrane must be dismantled and hand-cleaned. Outside services are available for cleaning and replacing membranes, though the potentially hazardous nature of the foulant or scalant may be a problem. The low concentration of chromium in the influent may require higher energy consumption to produce a highly concentrated recoverable waste stream.

In comparison with ion exchange, ED has a roughly equivalent effectiveness but is more expensive in capital, O&M, and waste disposal costs, and, thus, will not be considered in the future evaluation.

### **Direct Precipitation**

The direct precipitation of chromate as barium chromate ( $\text{BaCrO}_4$ ) by addition of barium carbonate has been reported and has been suggested as being useful for both barium and chromium recovery [6]. However, because of high barium salt costs and high effluent barium concentrations, this technology is not suitable for drinking water applications.

## **Biological Treatment**

This is a newly developed technology of using anaerobic sulfate-reducing bacteria to convert Cr(VI) in aqueous solution to Cr(III). The pH of water is maintained between 6.75 and 9.5. Sulfate and carbon source also are required to promote microbial growth. The sulfate reducing bacteria reduce sulfate to hydrogen sulfide. The hydrogen sulfide will then reduce Cr(VI) to Cr(III), which precipitates as insoluble chromium hydroxide [15,16].

This process is still under development and will not be considered in the future evaluation.

## **Other Technologies**

Other technologies such as evaporation, freeze concentration, and crystallization are used in industry for chromium recovery, but are not applicable to the low-concentration high-flow rate conditions of Glendale South OU.

Reduction of chromate with hydrazine also is not applicable because of the toxicity of residual hydrazine.

## **Summary**

From the above analysis, the advantages and disadvantages of each treatment technologies are summarized in Table 1. The following treatment technology will be evaluated further for alternative development:

- Ferrous reduction and precipitation
- Electrochemical reduction and precipitation
- Ion exchange

## **Treatment Evaluation**

This section evaluates the chromium treatment options identified applicable to the Glendale South OU groundwater during the treatment technology screening. The evaluation process is based on the nine evaluation criteria developed by EPA. In the Glendale South Operable Unit Feasibility Study Report, a nine-criteria analysis has been performed on the overall alternatives [1]. The evaluations performed in this section will focus on the additional impact due to the chromium removal technologies evaluated.

In performing the treatment technology evaluations, the following assumptions were adopted:

- The maximum concentration of total chromium in the groundwater is 1.2 mg/l.



<p align="center"><b>Table 1</b> <b>Summary of Treatment Technology Screening</b></p>			
<b>Treatment Technology</b>	<b>Advantages</b>	<b>Disadvantages</b>	<b>Further Evaluation</b>
Alum coagulation, sedimentation, filtration, and carbon adsorption	Conventional water treatment technologies, familiar to water treatment plant operators.	Still at research stage for chromium removal, no full scale application, may not be effective to meet treatment goal.	No
Chemical reduction with sulfur dioxide and precipitation	Proven technology, package treatment unit available, produces less sludge than ferrous reduction	Require two pH adjustments not suitable for high-flowrate applications, sulfur dioxide leaks may produce unpleasant smell or even health hazard.	No
Ferrous ion reduction and precipitation	Proven technology, package treatment unit available, no pH adjustment required, simple equipment, low capital cost	Large quantity of sludge requires offsite disposal	Yes
Electrochemical reduction with steel plate electrode	Proven technology, package treatment unit available, suitable to low-concentration applications, no pH adjustment required, minimal chemical handling facility required	Large quantity of sludge requires offsite disposal	Yes
Ion Exchange	Proven technology, produces highly concentrated solution for chrome reuse or sale.	High capital and O&M cost, operation complexity. Potential high brine disposal cost.	Yes
Reverse osmosis	Proven technology, can remove other contaminants such as nitrate.	High capital and O&M cost relative to ion exchange, complicated operations, large volume of waste stream, high cost for waste stream reduction or disposal	No
Electrodialysis	Proven technology, can remove other contaminants such as nitrate.	High capital and O&M cost relative to ion exchange, requires careful operations	No
Direct precipitation	Low capital cost, simple equipment	Not applicable to drinking water applications	No
Biological Treatment		Still under development, no full scale application, may not be applicable to drinking water applications.	No

- The treatment goal is total chromium level of 0.05 mg/l (state MCL for chromium).
- Since no speciation information was available, it was assumed that the chromium exists in the groundwater is Cr(VI) because it is more soluble and has greater toxicity.
- The full extraction stream (2,000 gpm) needs to be treated because of high removal percentage requirement.
- In the cost analysis, capital and operation and maintenance (O&M) costs have an accuracy of +50 percent to -30 percent, as required by the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA [17]. The present worth assumes an interest rate of 10 percent and a project life of 12 years. These factors are consistent with those used in the Glendale South OU Feasibility Study Report.

The summary of design criteria for all three treatment options are presented in Table 2.

### **Ferrous Reduction and Precipitation**

Figure 1 shows the schematic diagram of a commercially available package unit that adds ferrous chloride to remove Cr(VI). This package has been applied widely in the industry for chromium removal and is capable of consistently producing water which contains less than 0.05 mg/l of total chromium. Recently, there were two 4,000-gpm package units installed for chromium and other heavy metals removal [8]. Details of this package unit are in Appendix A.

As indicated on Figure 1, influent groundwater is first pumped in an equalization tank used to collect and homogenize the influent and recycled streams (decant and filtrate from sludge dewatering processes). The water will then be pumped to a reactor. A ferrous chloride solution will be injected into the water prior to entering the reactor. The pH in the reactor will be maintained at 7.5 to 8.0 using sodium hydroxide as the base. Air will be introduced into the reactor using the specially designed air sparge system. Air requirements will be minimal. The Cr(VI) in the groundwater will react with ferrous ion and form Cr(III). Cr(III) and ferric will then form hydroxide precipitates.

The treated water will enter the flash mix chamber of the clarifier where anionic polymer will be injected. The polymer will then react with solids to form a large particle size in the flocculation chamber. The flocculated solids will enter the clarifier where they will settle to the bottom by gravity. The clarified water will then be filtered (not included in the package unit) by a polishing mixed media filter. The purpose of adding a polishing filter is to safeguard against the chromium hydroxide and ferric hydroxide solids that may carry over from clarifier.

**Table 2**  
**Summary of Design Criteria**  
**(Design flow = 2000 gpm)**

<b>Ferrous Reduction and Precipitation System</b>		
Reactor	Detention time	30 minutes
Contact Clarifier	Detention time	60 minutes
Pressure Filter	Hydraulic loading	6 gpm/square foot
Sludge Thickening Tank (cone bottom)	Volume	5000 gallons
Filterpress	Capacity	45 cubic feet
<b>Electrochemical Reduction and Precipitation System</b>		
Electrochemical Cell	Number of cells	7
	Detention time	5 minutes
Retention Tank	Detention time	20 minutes
pH Adjustment Tank	Detention time	20 minutes
Contact Clarifier	Detention time	60 minutes
Pressure Filter	Hydraulic loading	6 gpm/square feet
Sludge Thickening Tank (cone bottom)	Volume	5000 gallons
Filterpress	Capacity	12 cubic feet
<b>Ion Exchange System</b>		
Ion Exchange Columns	Number of columns	6
	Diameter	10 feet
	Height	14 feet
	Resin type	Anion, weak base
	Resin bed depth	8 feet
	Surface flux	5.2 gpm/square foot
	Volume flux	0.74 gpm/square foot
Chemical Storage Tanks	Number of tanks	2
	Volume	3500 gallons/tank
Regeneration System	Number of systems	1

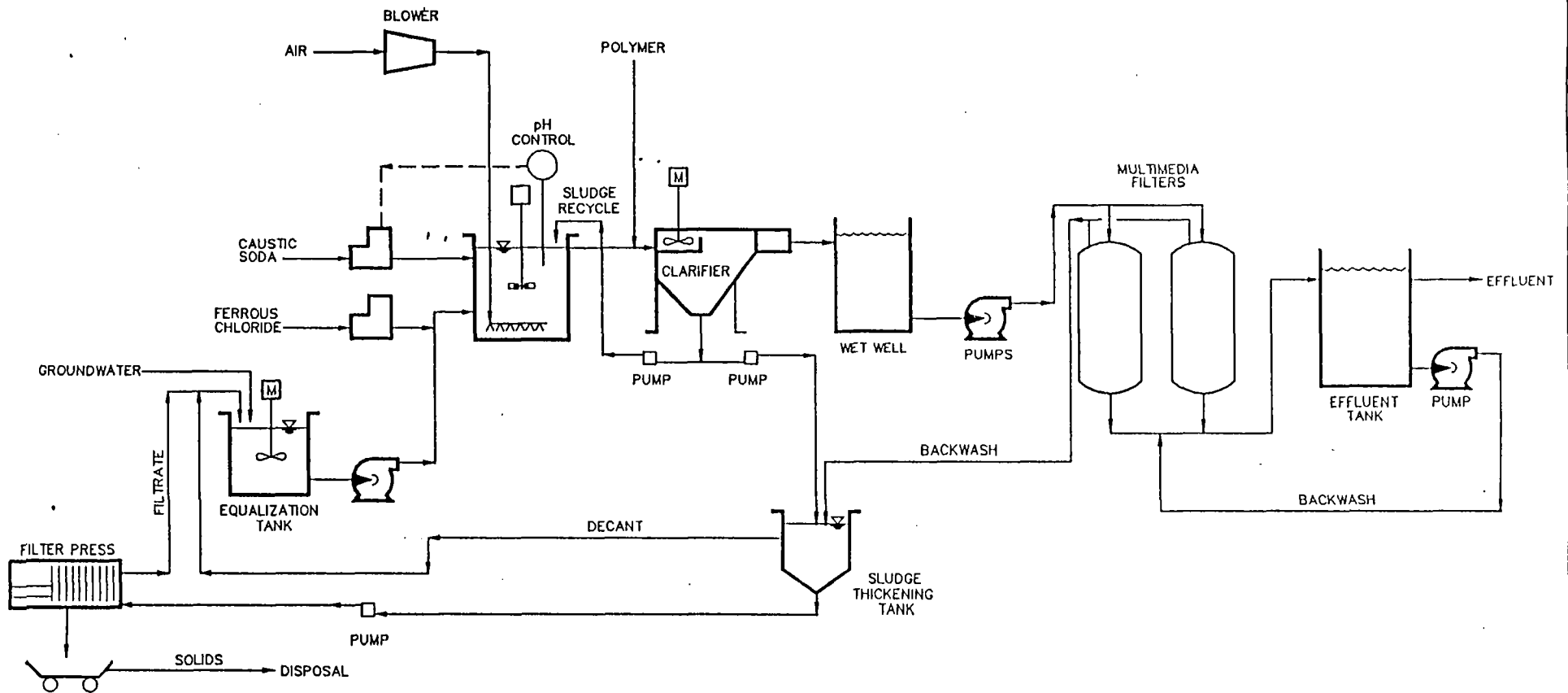


FIGURE 1  
FERROUS ION REDUCTION  
AND PRECIPITATION  
PROCESS FLOW DIAGRAM



Some of the solids collected in the bottom of the clarifier will be continuously recirculated to the reactor to aid in the treatment process. The remaining solids will be transferred to the sludge holding tank for thickening and subsequent feed to a filter press. Sludge collected in the sludge holding tank will be periodically sent to a recessed chamber filter press for further dewatering. The solids content of the filter cake is projected to be 30 percent to 35 percent. Sludge quantity is estimated at 45 cubic feet per day. The dewatered sludge will be taken offsite for disposal.

The sludge produced in the ferrous reduction and precipitation process is considered hazardous waste based on total chromium content. However, because the chromium in sludge cake is exclusively Cr(III) and chromium hydroxide is very stable, the sludge may be exempt from being categorized as hazardous waste. This will have significant impact on the cost of sludge disposal. More complete analysis of sludge quality in the future is required before a decision can be made. In this analysis, it is assumed that the sludge produced will be disposed of as hazardous waste.

**Protection of Human Health and the Environment.** The treated water of ferrous reduction and precipitation system will meet the drinking water regulation of 0.05 mg/l of total chromium and will protect human health. Removing chromium from extracted groundwater will also reduce chromium contamination in the aquifer and protect the environment.

**Compliance with ARARs.** The treated water will meet drinking water regulations for chromium. Offsite disposal of sludge is available and would be accomplished in compliance with all requirements applicable at the time of such offsite disposal. If this treatment system is installed before VOC treatment, the off-gas from the reactor due to air sparging may require treatment. The off-gas treatment can be achieved by adding a small vapor-phase GAC unit. If this treatment configuration results in the emission of greater than 1 pound per day of VOCs to the air, compliance with South Coast Air Quality Management District (SCAQMD) regulations (Chapter 6, Glendale RI) will be required.

**Long-Term Effectiveness.** The extent of chromium contamination in the aquifer is not well-defined at this time. The overall removal of chromium over the life of this project can not be evaluated. However, chromium will be permanently removed from the groundwater system along with VOCs during the extraction of groundwater. Therefore, the future risk of chromium contamination at the project site will be reduced.

**Reduction of Toxicity, Mobility, or Volume through Treatment.** Cr(VI) will be reduced to Cr(III) and precipitate out of solution during the treatment. Since Cr(III) is much less toxic than Cr(VI), the toxicity is reduced. Cr(III) will form stable chromium hydroxide at near neutral pH, and the mobility of chromium is reduced through treatment. Although chromium is transferred to sludge form, the overall volume of chromium contamination is greatly reduced through extraction and treatment, although chromium is transferred to sludge form.

**Short-Term Effectiveness.** As discussed earlier, the ferrous reduction system can meet the state drinking water MCL for chromium. The package treatment unit is compact and easy to install. The impact during construction will be minimal. The sludge cake produced can

be carried offsite at about one truckload a day and will not have major impact on neighborhood traffic.

**Implementability.** The ferrous reduction process is a proven and widely applied technology for Cr(VI) removal. A simple pilot test may be required before designing this system to refine chemical dosage and design criteria. A properly designed and operated system is capable of consistently producing treated water of less than 0.05 mg/l of total chromium. The ferrous reduction system can be fabricated at the treatment capacity required. With an additional filter, this package can be added either before or after VOC treatment processes. Although the sludge produced may be classified as hazardous waste in California because of chromium content, it is easy to handle (30 to 35 percent solid content sludge cake) and off-site disposal is available.

**Cost.** The cost for major purchased equipment of this treatment option is \$947,000. This includes a package treatment unit, a mixed media filter system, an equalization tank, and pumps. The total capital requirement (TCR), which includes site preparation, contingencies, and contractors overhead and profit, is \$2,870,000. The annual operations and maintenance cost is estimated at \$574,000. This cost includes the cost of sludge disposal to hazardous landfill. If the sludge can be exempt as hazardous waste, the sludge disposal cost will be significantly lower. The total present worth is estimated at \$6,780,000. Table C-1 presents a summary of capital and O&M costs (Appendix C).

**State Acceptance.** The removal of chromium will meet state regulations and protect public health. The state was provided with an opportunity to review the draft proposed plan that included a description of ferrous reduction and precipitation, and electrochemical reduction and precipitation. The state indicated it had no objections.

**Public Acceptance.** The removal of chromium will protect human health and help remediate groundwater. Public comment will be solicited during the public comment period.

### **Electrochemical Reduction and Precipitation**

The electrochemical reduction technology uses sacrificial steel plate electrodes to produce ferrous ions which reduces Cr(VI) to Cr(III). Figure 2 shows the schematic diagram for a package treatment unit using electrochemical reduction. Details of this package unit are in Appendix B.

Groundwater is pumped into an equalization tank where it will be mixed with decant and filtrate from the sludge dewatering process. The water is then pumped into an electrochemical cell where Cr(VI) was reduced to Cr(III). A moderate DC current is required to release ferrous ion from steel plates into solution to react with Cr(VI). The steel plate electrodes need to be cleaned regularly and replaced approximately every 3 months [11].

Following electrochemical reduction, treated water goes to a retention tank (20 minutes) for complete reaction, and then to a pH adjustment tank which maintains the pH of water at 7.8 to 8.0 to enhance chromium hydroxide precipitation. After pH adjustment, the water

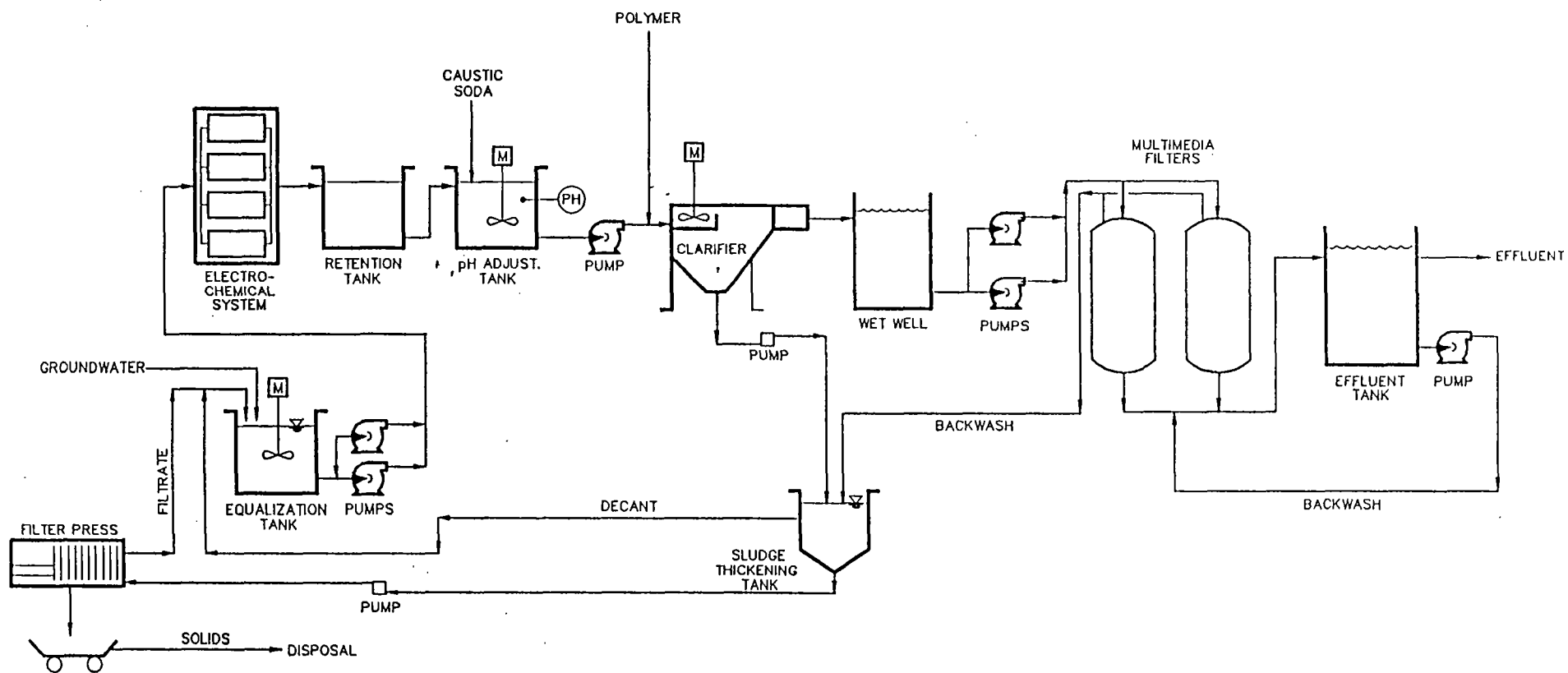


FIGURE 2  
ELECTROCHEMICAL REDUCTION  
AND PRECIPITATION  
PROCESS FLOW DIAGRAM



goes through similar contact clarification and filtration processes as that in the ferrous reduction and precipitation system. All the solids from the clarifier will be decanted and dewatered for offsite disposal.

Sludge production of this process is estimated at 24 cubic feet per day by the package unit manufacturer [11]. This is significantly lower than the estimation of the ferrous reduction system manufacturer. Since the chemical stoichiometry is the same for both of these processes, the sludge production should be similar. The 45 cubic feet per day estimate by the ferrous reduction system manufacturer seems more reasonable and will be used for process evaluation and cost estimate.

This treatment process is similar to ferrous reduction in many ways, such as in process chemistry, treatment efficiency, and sludge production and disposal. Thus, the evaluation of protection of human health and the environment; reduction of toxicity, mobility, or volume through treatment; long-term and short-term effectiveness; and state and public acceptance are the same as in the discussion of the ferrous reduction process, and will not be repeated here.

**Compliance with ARARs.** The treated water will meet drinking water regulations for chromium. Offsite disposal of sludge is available and would be accomplished in compliance with all requirements at the time of such offsite disposal.

**Implementability.** The electrochemical process is a proven and widely applied technology for Cr(VI) removal. A simple treatability test may be required before designing this system to refine design criteria and sludge production. A properly designed and operated system is capable of consistently producing treated water of less than 0.05 mg/l of total chromium. The treatment system can be fabricated at the treatment capacity required. The treatment package comes with a media filter and can be added either before or after VOC treatment processes. Although the sludge produced may be classified as hazardous waste in California due to chromium content, it is easy to handle and offsite disposal is available.

**Cost.** The cost for major purchased equipment of this treatment option is \$1,700,000. The package treatment unit comes with all the process modules, tanks, and pumps shown on Figure 2 and with interconnecting pipes, valves, and fittings. The total capital requirement (TCR), which includes site preparation, contingencies, and contractors overhead and profit, is \$4,130,000. The annual operations and maintenance cost is estimated at \$520,000. This cost also includes the cost of sludge disposal to hazardous landfill. If the sludge can be exempt as hazardous waste, the sludge disposal cost will be significantly lower. The total present worth is estimated at \$7,880,000. Table C-2 presents a summary of capital and O&M costs.

## **Ion Exchange**

Ion exchange is a proven technology of advance water treatment for water softening (calcium and magnesium removal) and removal of specific heavy metal ions and anions. A schematic diagram of a typical ion exchange process is shown on Figure 3. The process



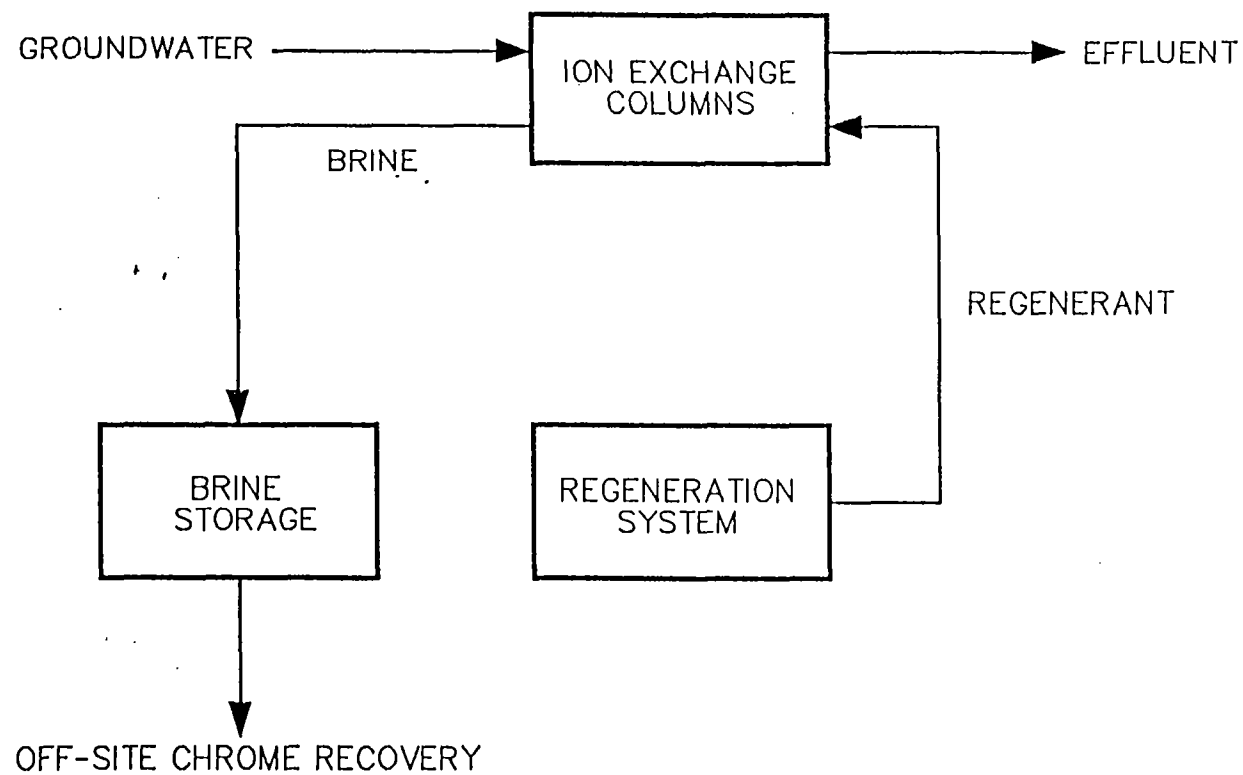


FIGURE 3  
ION EXCHANGE  
PROCESS FLOW DIAGRAM



equipment includes six anion exchange columns (10 feet in diameter and approximately 14 feet tall) with a sodium hydroxide regeneration system. Detailed design criteria are presented in Table 2. The full stream of groundwater (2,000 gpm) will need to be treated. The effluent total chromium concentration is expected to be less than 0.05 mg/l. Nitrate will be removed together with chromate.

The exhausted ion exchange column will be regenerated with sodium hydroxide and conditioned with sulfuric acid before the column resumes service. The production of spent regenerant is approximately at a rate of 15,000 gallons per month. The waste stream which contains approximately 5 percent of sodium chromate is considered hazardous waste. However, this waste stream can be further concentrated and reused industrially. Local chromate recovery service is available. The cost for taking the spent regenerant offsite for further treatment and reuse is approximately \$0.53 per gallon.

**Protection of Human Health and the Environment.** Ion exchange is capable of removing total chromium to below MCL (0.05 mg/l) for the protection of human health. Removing chromium from extracted groundwater also will reduce chromium contamination in the aquifer. The chromium removed from groundwater through ion exchange can be reused industrially and, thus, protect the environment.

**Compliance with ARARs.** The treated water will meet state drinking water MCLs for chromium. Spent regenerant will be conveyed offsite for treatment and potential recovery of chromate; these offsite actions will be conducted in accordance with all requirements applicable at the time.

**Long-Term Effectiveness.** See discussion of long-term effectiveness for the ferrous reduction system.

**Reduction of Toxicity, Mobility, or Volume Through Treatment.** The chromate will concentrate on ion exchange resin in hexavalent form. The sodium chromate concentration in the spent regenerant is approximately 5 percent. The volume of contamination is greatly reduced through ion exchange. After regeneration, sodium chromate can potentially be further reused industrially or chemically reduced to the Cr(III) state in a small treatment system.

**Short-Term Effectiveness.** Ion exchange can consistently remove Cr(VI) to less than 0.05 mg/l during the lifetime of this project. The waste stream generated is hazardous because of chromate content and needs to be handled and transported with care. The frequency of waste stream transferral is about once every 10 days and will not have a major impact on neighborhood traffic.

**Implementability.** Ion exchange has been used in industry for chrome recovery. The waste from regeneration is approximately 5 to 6 percent in sodium chromate concentration. The waste can be conveyed offsite for chrome recovery. Local chrome recovery service is available. Further discussion of waste brine disposal is included in the Glendale South OU Feasibility Study Report, page 6-26.

**Cost.** The major equipment for the ion exchange system includes six ion exchange columns, regenerant storage and feed system, and spent regenerant storage. The cost for major purchased equipment of this treatment option is \$3,070,000. The total capital requirement (TCR), which includes site preparation, contingencies, and contractors overhead and profit, is \$8,370,000. The annual operations and maintenance cost is estimated at \$1,360,000. This cost includes the cost of offsite recovery of spent regenerant. The total present worth is estimated at \$15,800,000. If sufficient nitrate is removed from the groundwater, some cost savings could be realized by eliminating the need for a nitrate blending facility. Table A-3 presents a summary of capital and O&M costs.

**State Acceptance.** The removal of chromium would meet state regulations and protect public health.

**Public Acceptance.** The removal of chromium would protect human health and clean up groundwater. Public comment will be solicited during the public comment period.

### Summary of Treatment Evaluation

Table 3 summarizes the results of nine-criteria analysis. All three technologies are proven technology and widely used for chromium removal. The treated water would meet drinking water regulations for chromium.

### References

1. James M. Montgomery, Inc. *Feasibility Study for the Glendale Study Area South Operable Unit*, August, 1992.
2. Hannah, S.A. M. Jelus, and J.M. Cohen. "Removal of Uncommon Tract Metals by physical and Chemical Treatment Processes," *J. Water Poll. Control, Fed.* 49(1977): 2297—2309.
3. Maruyama, T., S.A. Hannah, and J.M. Cohen. "Removal of Heavy Metals by Physical and Chemical Treatment Processes," *J. Water Pool. Control. Fed* 47 (1975): 962-975.
4. U.S. EPA (U.S. Environmental Protection Agency) (1971). *An Investigation of Techniques for Removal of Chromium from Electroplating Wastes. Water Pollution Control Research Series. Project 12010 ETE*, Battelle Columbus Lab.
5. Alaerts, G.J., V. Jitjaturunt and P. Kelderman, "Use of Coconut Shell-Based Activated Carbon for Chromium (VI) Removal", *Wat. Sci. Tech. Vol. 21*, pp.1701-1704, 1989.
6. Patterson, J.W., *Industrial Wastewater Treatment Technology*, 2nd. ed., 1985.

**Table 3**  
**Summary of Nine-Criteria Analysis**

<b>Criteria</b>	<b>Ferrous Reduction and Precipitation</b>	<b>Electrochemical Reduction and Precipitation</b>	<b>Ion Exchange</b>
Protection of Human Health and Environment	Will meet drinking water standard for chromium. Will reduce chromium contamination in the aquifer to some extent.	Will meet drinking water standard for chromium. Will reduce chromium contamination in the aquifer to some extent.	Will meet drinking water standard for chromium. Will reduce chromium contamination in the aquifer to some extent.
Compliance with ARARs	Will meet drinking water regulations for chromium. Sludge will be disposed of offsite. SCAQMD ARARs will be met.	Will meet drinking water regulations for chromium. Sludge will be disposed of offsite.	Will meet drinking water regulations for chromium. Spent regenerant reuse service is available locally.
Long-Term Effectiveness	Will reduce the risk of chromium contamination in aquifer.	Will reduce the risk of chromium contamination in aquifer.	Will reduce the risk of chromium contamination in aquifer.
Reduction of Toxicity, Mobility, or Volume through Treatment	Toxicity, mobility, and volume are all reduced through treatment.	Toxicity, mobility, and volume are all reduced through treatment.	Volume of contamination will be reduced. Waste can be further treated for industrial reuse.
Short-term Effectiveness	Proven technology. Will meet drinking water regulations.	Proven technology. Will meet drinking water regulations.	Proven technology. Will meet drinking water regulations. Will also remove nitrate.
Implementability	Package unit is available. Sludge offsite disposal is available.	Package unit is available. Sludge offsite disposal is available.	Weak base resin is effective in removing chromium. Spent regenerant can be shipped offsite for industrial reuse.
Cost:			
Capital Cost	\$2,870,000	\$4,130,000	\$8,370,000
Annual O&M Cost	\$574,000	\$520,000	\$1,360,000
Total Present Value	\$6,780,000	\$7,880,000	\$15,800,000
State Acceptance	State has expressed no objections to this alternative.	State has expressed no objections to this alternative.	State acceptance is anticipated.
Public Acceptance	Public acceptance will be solicited.	Public acceptance will be solicited.	Public acceptance is anticipated.

7. Cullinan, M.J. jr. and J.D. Dietz. "Treatment of Plating Wastes from the Automotive Industry," *Ind. Wastes* (March/April 1978); 29-32.
8. Unical Chemical Division, Unical Corporation, Personal Communication.
9. Kraljik, J. "Practical Guide to Treatment of Chromium Waster Liquors," *Metal Fin.* (9175): 49-55.
10. USEPA, "Economics of Wastewater Treatment Alternatives for the Electroplating Industry," *USEPA Technology Transfer Report EPA 625/5-79-016* (June 1979).
11. Andco Environmental Processes, Inc., Personal Communication.
12. Crampton, P. And R. Wimoth. "Reverse Osmosis in the Metal Finishing Industry", *Metal Fin.* (March 21-27, 1982).
13. "RO Membranes Affected by Solvents in Ground Water", *The Hazardous Waste Consultant*: July/August 1992.
14. Richardson, E.W., E.D. Stobbe, and S. Bernstein. "Ion Exchange Traps Chromates for Reuse," *Environ. Sci. Technol.* 2 (1968): 1006-1016.
15. "Bioremediation of Hexavalent Chromium Wastewaters", *The Hazardous Waster Consult*, July/August 1992.
16. Komori, K., A. Rivas, K. Toda, and H. Ohtake, "Biological Removal of Toxic Chromium Using and Enterobactro Clacae Strain that Reduces Chromate under Anaerobic Conditions", *Brotechnology and Bioengineering*, Vol. 35, pp. 951-954 (1990)
17. USEPA, "Guidance for Conducting Remedial Investigation and Feasibility Studies Under CERCLA, Interim Final," *Office of Emergency and Remedial Response OSWER Directive 9355.3-01.* (1988)

## **Appendix A**

### **Ferrous Reduction and Precipitation System**

Unocal Chemicals & Minerals Division  
Unocal Corporation  
1511 East Orangethorpe Avenue  
Fullerton, California 92631  
Telephone (714) 525-9225  
Facsimile (714) 525-5758

**UNOCAL** 

September 10, 1992

Unipure

Mr. David Chang  
CH2M Hill  
2510 Red Hill Avenue  
Santa Ana, CA 92705

Dear Mr. Chang:

Thank you for the opportunity to further detail a UNIPURE Treatment System. From the information provided I have generated the following quote which includes a budgetary capital investment figure, an equipment list, a process flow diagram, a process flow description, a description of the Engineering Services provided by Unipure, estimated operating parameters and UNIPURE Treatability Data for hexavalent chromium containing streams.

As soon as possible, our technical staff would like the opportunity to perform a bench-scale treatability test on a representative one gallon sample of the groundwater. The results of the test will allow us to demonstrate Unipure's treatment capabilities with the water, refine the estimated operating parameters for the full scale system, refine my equipment proposal and most importantly provide an effluent guarantee to your client.

If you have any questions on this information, please do not hesitate to contact me at (714) 447-5535. I look forward to working with you on this project.

Sincerely,



Michael B. McPhee  
Sales Manager  
UNIPURE

SUMMARY

Based on the information provided, the following has been generated to describe the UNIPURE Equipment and Services which will enable your client to meet the proposed hexavalent chromium requirement.

<p>TOTAL CAPITAL INVESTMENT 2000 GPM UNIPURE TREATMENT SYSTEM</p>
---

UNIPURE EQUIPMENT AND TECHNICAL SERVICES.....\$ 685,850

SCOPE OF WORK

From the information generated by either the proposed laboratory testing, a pilot study or from your specifications UNIPURE will generate a final design package. This package will detail the Unipure supplied equipment and assist CH2M Hill and your client in the installation of the UNIPURE Treatment System.

After the successful installation and mechanical commissioning of the equipment, a Unipure Technical Support Representative will start-up the system and train the permanent operators. Five (5) days of on-site start-up and training services are included in the above quotation.

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Notes:

- 1 The quote does not include pricing for materials or labor for any interconnecting piping or electrical wiring between modules or any stand alone components.
- 2 Freight charges and travel & living expenses for Unipure Field Personnel are not included in the above quote. Those charges will be billed separately at Unipure's current T&M schedule.



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EQUIPMENT DESCRIPTION/UNIPURE TREATMENT SYSTEM  
2000 GPM MAXIMUM PROCESS CAPACITY

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UNIPURE REACTOR 45K MODULE

Includes:

LICENSE AND COMPLIANCE GUARANTEE  
field fabricated open top FRP tank  
variable speed mixer  
air sparge system with flow meter  
pH probe and controller  
ferrous injection pump  
base injection pump  
control panel  
piping and valves (installed)  
electrical controls and wiring (installed)

UNIPURE Clarifier CL45F Module

Includes:

lamella type clarifier with removable FRP plates  
coal tar epoxy coated steel  
attached flash mix/flocculation chambers  
flash chamber mixer  
flocculation chamber mixer  
variable speed controller  
STRANCO polymer addition system  
sludge recycle pump  
sludge transfer pump  
piping and valves (installed)  
electrical controls and wiring (installed)

OTHER EQUIPMENT

(2) CHEMICAL STORAGE TANKS

6500 gallon, XLPE tank  
flat bottom, closed top

SLUDGE HOLDING TANK

5000 gallon, XLPE tank  
cone bottom, open top  
with stand

FILTERPRESS

\*45 cubic foot, w/ feed pump  
non-gasketed plates  
air blow down manifold  
automatic pump control system  
semi-automatic plate shifter  
(2) sludge bins

\* Sized for (1) cycle per day

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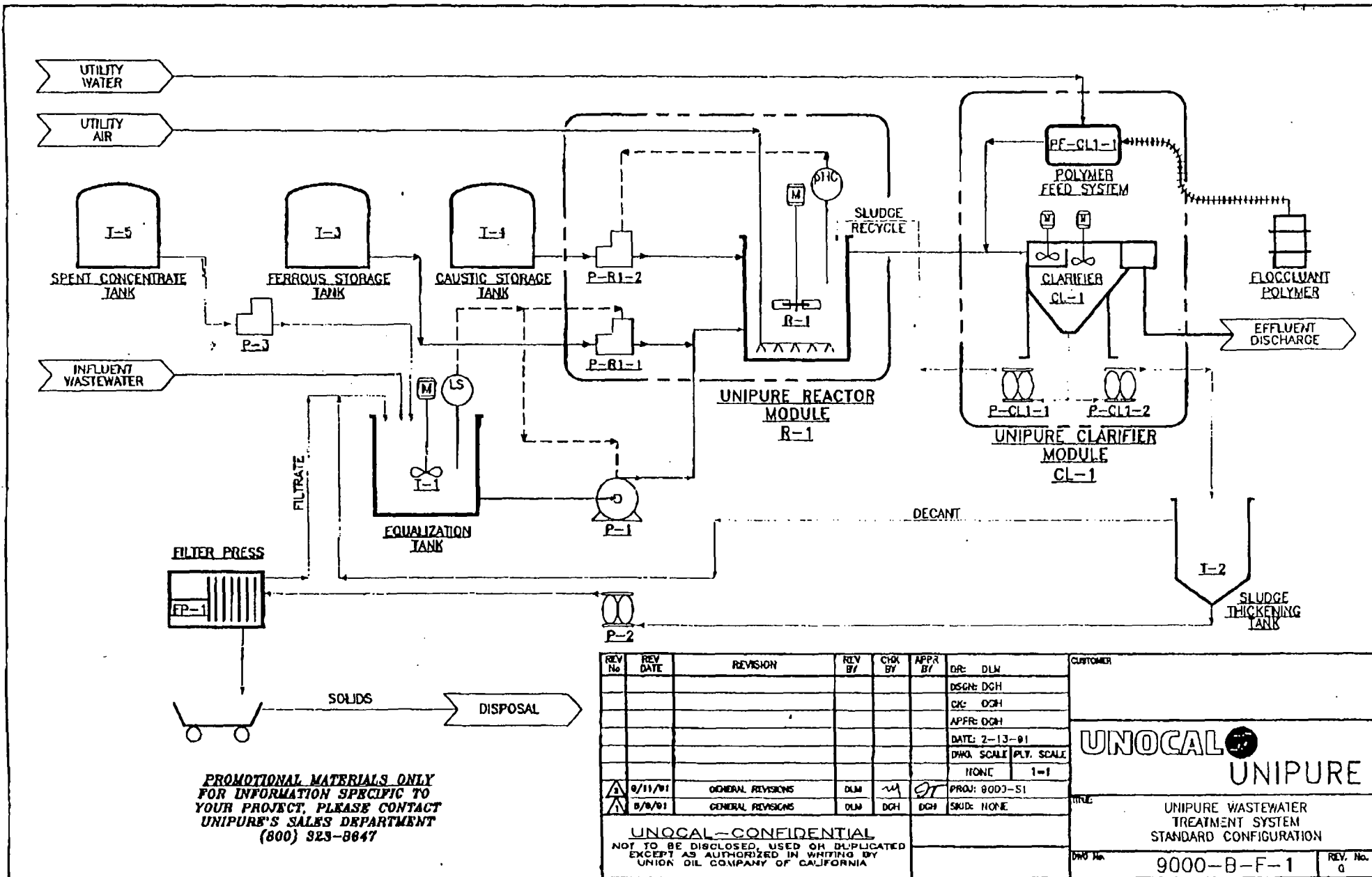
EQUIPMENT DESCRIPTION/UNIPURE TREATMENT SYSTEM  
2000 GPM MAXIMUM PROCESS CAPACITY

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(continued)

FILTRATE SUMP TANK

600 gallon XLPE tank  
flat bottom, open top  
w/ level controls  
w/ air diaphragm transfer pump



## PROCESS FLOW DESCRIPTION 2000 GPM UNIPURE TREATMENT SYSTEM

### COLLECTION AND EQUALIZATION

An equalization tank or holding tank (supplied by others) will be used to collect and homogenize the groundwater. The water will then be pumped at a maximum flowrate of 2000 GPM to the UNIPURE Reactor.

### FERROUS IRON ADDITION

A ferrous chloride or ferrous sulfate solution will be injected into the water prior to entering the UNIPURE Reactor. The ferrous addition system consists of a chemical storage tank for the ferrous solution and a chemical injection pump which is supplied with the Reactor Module.

### METALS PRECIPITATION

The water containing ferrous iron and heavy metals will enter the UNIPURE Reactor. The pH in the Reactor will be maintained at 7.5 -8.0 using sodium hydroxide as the base. A chemical injection pump supplied with the Reactor Module will be used to deliver sodium hydroxide from the chemical storage tank.

Air will be introduced into the Reactor using the specially designed air sparge system included with the Reactor. Air requirements will be minimal. If an air compressor and/or blower are not currently available, Unipure can supply either at additional cost.

The heavy metals will be precipitated in the UNIPURE Reactor using UNIPURE Process Technology. The solids laden water will flow by gravity to the UNIPURE Clarifier/Flocculator Module.

### FLOCCULATION/CLARIFICATION

The treated water will enter the flash mix chamber of the Clarifier/Flocculator Module where anionic polymer will be injected from the polymer addition system. The polymer will then react with the Unipure solids to form a large particle size in a slowly mixed flocculation chamber. The flocculated solids will enter the main body of the clarifier where they will settle to the bottom by gravity. The clean, clarified water will then be decanted to discharge.

Some of the solids collected in the bottom of the Clarifier/Flocculator will be transferred to the UNIPURE Reactor to aid in the treatment process. The remaining solids will be transferred to the sludge holding tank for thickening and subsequent feed to a filter press. All pumps required for the operation of the clarification step are included in the module.

### SLUDGE DEWATERING

Sludge collected in the sludge holding tank will be periodically sent to a recessed chamber filterpress for further dewatering. The solids content of the filter cake is projected to be 30% to 35%.

### ENGINEERING SERVICES

Detailed engineering services will be provided to ensure the successful implementation and start-up of the UNIPURE Treatment System.

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### ENGINEERING SERVICES PROVIDED BY UNIPURE

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#### PROCESS FLOW DIAGRAM

#### PROCESS & INSTRUMENTATION DIAGRAM

#### EQUIPMENT LAYOUT

- General Layout

- Tank Drawings

- Filterpress Data Sheets

#### ELECTRICAL

- Control Panel Drawing

- Specifications

#### MODULE DRAWINGS

- Reactor Package

- Clarifier Package

- O&M Manuals

- Specifications

#### UNIPURE PROCESS START-UP

- Operator training

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OPERATING PARAMETERS  
2000 GPM UNIPURE TREATMENT SYSTEM

The following estimated operating parameters are based on the described characteristics of the influent water and effluent discharge requirements.

BASIS: - 2000 GPM or 2.88 Mgd  
- 24 HOURS/DAY

A. CHEMICAL CONSUMPTION RATE

Ferrous chloride (39 wt%)	403 gallons/day
Caustic soda (25 wt%)	264 gallons/day
Polymer (100% Neat)	13 <del>gallons</del> <sub>lbs</sub> /day

B. SLUDGE GENERATION RATE

Cake (30% solids)	45 cu.ft./day
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C. UTILITY

Air	250 SCFM @ 100 psig
-----	---------------------

10/17/82  
11/1/82

## UNIPURE HEAVY METALS REMOVAL TECHNOLOGY

UNIPURE Process Technology employs a unique mechanism for heavy metals removal. This technology represents a substantial improvement on classical iron based coprecipitation.

UNIPURE iron based coprecipitation allows for dramatically increased heavy metals removal efficiency with a simultaneous reduction in sludge formation.

Heavy metals are trapped in an insoluble iron matrix. Entrapment occurs because heavy metals are coprecipitated when the iron is rapidly removed from the solution. In the UNIPURE process, classical coprecipitation is made more effective by associating the heavy metal with the iron molecules prior to coprecipitation. Heavy metals are associated with the iron in solution via an occlusion and adsorption type bonding. This creates a concentration or entropy effect that greatly enhances metals removal and also decreases iron requirements.

UNIPURE Process Technology allows the user to reduce the heavy metals concentrations to extremely low levels. It is common practice to exceed the EPA's primary and secondary drinking water standards for the regulated heavy metals. This coprecipitation of heavy metals is so effective, thermodynamic equilibrium laws are superseded. This is possible because UNIPURE relies on a kinetic process and, in fact, the reaction never reaches equilibrium. Therefore, the treated water can be treated repeatedly with additional heavy metals removal after every treatment. With UNIPURE it is possible to design wastewater treatment systems for any heavy metal removal standard. Current regulations for heavy metals removal do not require multiple UNIPURE treatments, but this ability will become important as regulations become more stringent.

## UNIPURE PROCESS TECHNOLOGY

Practice of the UNIPURE process requires three key elements:

- 1) A soluble ferrous iron source; either from spent pickling acids with high soluble iron or commodity chemicals such as ferrous chloride or ferrous sulfate.
- 2) An air source for oxidation.
- 3) A UNIPURE Reactor for implementation of the chemistry.

The proper implementation of the chemical reaction is critical for obtaining optimum heavy metals removal with minimum sludge formation. The UNIPURE Reactor series is designed specifically to provide the optimum conditions required to effect UNIPURE Technology under various maximum hydraulic flow conditions. Air is used as the oxidizer and this is supplied using a blower or utilizing plant air.

## UNIPURE BENEFITS

### COMPLIANCE

Unipure guarantees compliance with your heavy metals regulations.

### OPERATING COSTS

The operating pH of the UNIPURE system is 7.5 - 8.0 for all heavy metal containing streams. There is no need to raise the pH for precipitation and subsequently lower it for discharge. There is no need to spend money on additional chemicals for individual batch treatment of concentrates. Most concentrates are metered into the UNIPURE system with no separate treatment required.

The Unipure system employs traditional equipment and low cost commodity chemicals. Maintenance is relatively simple; no backwashing, regeneration or cleaning of expensive resins or membranes is required.

### SYSTEM FLEXIBILITY

Fluctuations in pH do not adversely affect UNIPURE Process Technology as long as those fluctuations are between 7.0 and 11.0.

The inherent coagulating ability and quick settling properties of the Unipure sludge mean that upsets in clarification are less likely to occur.

Operation at neutral pH makes the process less susceptible to problems associated with chelating and complexing agents.

### MODULAR SYSTEM

Unipure offers a cost effective, modular system for implementing all phases of wastewater or groundwater treatment. We realize that the requirements of each customer are unique. The modular concept was adopted to ensure flexibility while meeting the individual needs of our clients. Equipment, engineering and construction costs are minimized with the modular concept.



# UNIPURE PROCESS TECHNOLOGY

## OPERATING SYSTEM DATA

**CLIENT :** Metal Finishing (Captive Shop);  
350 gpm; NPDES Discharger

**WATER SOURCE :** Rinseswater Composite from  
Metal Finishing Lines

**TREATMENT SCHEME :** UNIPOLISH Configuration;  
Retrofit of a Competitive System

**CHEMICALS USED IN TESTING :** Sodium Hypochlorite for Cyanide Destruction  
Ferrous Chloride  
Caustic Soda 20 wt%  
Polymer for Flocculation Aid

### ANALYTICAL RESULTS :

METALS		AVERAGE INFLUENT CONCENTRATION	DISCHARGE REQUIREMENTS	UNIPURE EFFLUENT
Total Cr	(mg/l)	49.0	< .25	.01
Cr6	(mg/l)	8.0	< .05	< .01
Cd	(mg/l)	0.05	-	< .001
Co	(mg/l)	0.04	<1.0	.001
Cu	(mg/l)	50.0	< .20	.01
Ni	(mg/l)	15.0	< .50	.04
Pb	(mg/l)	2.0	-	< .001
Zn	(mg/l)	18.0	<1.0	.034

# UNIPURE PROCESS TECHNOLOGY

## BENCH SCALE TREATABILITY DATA

**CLIENT :** Metal Molding and Casting (Foundry);  
NPDES Discharger

**WATER SOURCE :** Rinseswater Composite from  
Metal Cleaning & Finishing Lines

**TREATMENT SCHEME :** Standard UNIPURE Configuration

**CHEMICALS USED IN TESTING :** Ferrous Chloride  
Caustic Soda 50 wt%

### ANALYTICAL RESULTS :

METALS	AVERAGE INFLUENT CONCENTRATION	UNIPURE EFFLUENT
Total Cr (mg/l)	49.0	.008
Cr6 (mg/l)	7.6	< .01
Cd (mg/l)	0.046	< .001
Cu (mg/l)	50.0	< .02
Pb (mg/l)	1.65	< .001
Ni (mg/l)	15.3	.02
Zn (mg/l)	18.0	.04

# UNIPURE PROCESS TECHNOLOGY

## BENCH SCALE TREATABILITY DATA

**CLIENT :** Site Remediation Company;  
NPDES Discharge

**WATER  
SOURCE :** Leachate from a Landfill

**TREATMENT  
SCHEME :** Standard UNIPURE Configuration

**CHEMICALS USED  
IN TESTING :** Ferrous Chloride  
Caustic Soda 50 wt%  
Hydrochloric Acid

### ANALYTICAL RESULTS :

METALS		AVERAGE INFLUENT CONCENTRATION	UNIPURE EFFLUENT
As	(mg/l)	.004	<.002
Cd	(mg/l)	.0044	<.0001
Cr	(mg/l)	.029	<.001
Cu	(mg/l)	.043	.014
Pb	(mg/l)	.020	<.001
Hg	(mg/l)	.0014	<.0001
Ni	(mg/l)	<.01	<.01
Ag	(mg/l)	.029	.005
Zn	(mg/l)	.46	.003

## **Appendix B**

### **Electrochemical Reduction and Precipitation System**



# **Andco Environmental Processes, Inc.**

595 Commerce Drive, Amherst, NY 14229-2380 (716) 691-2100/Fax (716) 691-2000

September 15, 1992

CH2M HILL  
2510 Red Hill Avenue  
Suite A  
Santa Ana, CA 92705

Attention: Mr. David Chang

Subject: **Andco Heavy Metal Removal System**  
(Our Proposal No. 12780)

## **Design Conditions**

We understand that you wish to treat 2000 gpm of groundwater that is contaminated with approximately 1.2 mg/l of hexavalent chrome.

You have represented to us that the influent will have the following analysis and that you require the effluent from the Andco system to be as specified below:

	<u>Influent</u> mg/l	<u>Required Effluent</u> mg/l
Hexavalent Chrome	1.2	0.05
Total Chrome	1.2-2.0	0.05
pH	~7	
Flow	2000 gpm	

The above effluent conditions should be achieved if the influent previously described has compounds which are below the following indicated concentrations:



Andco Heavy Metal Removal System  
September 15, 1992  
Page 2

<u>Compounds</u>	<u>Concentration Limit</u>
CN, $H_2O_2$ , $MnO_4^{-2}$ bleach and other oxidizing agents	2 mg/l
phosphates, $HNO_3$ , and emulsifiers	15 mg/l
oils, greases, detergents and surfactants	100 mg/l

If you expect to exceed the above concentration limits, Andco must be advised so that we can re-evaluate the proposed equipment to determine if the required effluent can be met.

In order to confirm our design and identify unusual conditions that may be unique to your processing operations at this early stage, it would be our intention to perform treatability tests in our laboratory on representative wastewater samples. In that way, our system design can be further tailored to your specific conditions and effluent compliance can be further assured.

Any system modifications and/or scope changes resulting from our lab tests would be presented to you for review and approval.

Sludge from the filter press should be approximately 30% solids. Sizing is based on zero suspended solids in the influent stream unless otherwise stated under design conditions.

#### Equipment Acceptance Testing

The Andco Heavy Metal Removal System has been installed in over 200 treatment applications to meet very demanding effluent requirements. The system specified in this proposal has been designed to meet your effluent requirements, as stated under Design Conditions, based on the compliance to preconditions and the influent analyses that are stated above. The design is also contingent upon the successful treatment of a representative influent sample tested at our Amherst, New York, facility.

Start-up of equipment under the supervision of an Andco engineer will include sampling of influent and effluent streams to and from the Andco system over a continuous 24-hour period of normal operation of customer's production equipment. Samples thus obtained will be analyzed by a mutually agreed upon laboratory. If analysis is within the influent and effluent design conditions as stated above, the performance test will be deemed successful and all parties will sign the acceptance document.



One	(1)	Model "7F" Heavy Metal Removal System Skid with the following major components:
One	(1)	Single pH control system
Two	(2)	Process feed pumps
Seven	(7)	Electrochemical cells with electrodes and cell power supply, piped in parallel flow configuration for independent operation and maintenance
One	(1)	Motor control center
One	(1)	CRT/operator interface panel with computer, control screen, expanded PLC and Genesis software package
One	(1)	Self-contained automatic acid wash system
One	(1)	Retention tank
One	(1)	pH adjust tank
One	(1)	Mixer for above
One	(1)	Polymer feed system
Two	(2)	Clarifiers in parallel flow configuration with sludge recycle, with built-in thickening tanks
Two	(2)	Sludge transfer pumps



**Andco Heavy Metal Removal System**  
**September 15, 1992**  
**Page 4**

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- One (1) Filter press, 12 cubic foot capacity
- One (1) Multi-media filter system  
 consisting of:
  - One (1) Tank with level controls
  - Two (2) Filter feed pumps with flow control (one operational,  
 one built-in spare)
  - Six (6) Vessels with media, piped in parallel flow  
 configuration for independent operation and  
 maintenance
  - One (1) Backwash pump
  - One (1) Effluent holding tank
- One (1) Set PVC pipes, valves and fittings on packaged skids
- One (1) Set electrical components, PVC conduits, and wiring  
 on packaged skids
- One (1) Set interconnecting piping between "packaged units"  
 for field installation by customer
- One (1) Set interconnecting electrical between "packaged unit"  
 for field installation by customer

**Engineering and Support Services**

As an integral part of Andco's scope of work, our project team would prepare the following documents for your system:

1. Project Drawing Package:
  - General Arrangement
  - P&I Diagram
  - Interconnecting Piping & Conduit Arrangement





Andco Heavy Metal Removal System  
September 15, 1992  
Page 5

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- Electrochemical Skid
  - Electrical Schematics
  - Control Panel Layout
  - Clarifier
  - Multi-Media Filter
  - Filter Press

NOTE: Additional drawings may be provided depending upon system configuration.

2. Complete System Operation/Maintenance Manual (3 supplied):
  - Installation Section
  - Operation Section
  - Maintenance Section
  - Component Parts Section with Equipment
  - Data Sheets

Our engineering department can also undertake specialty tasks associated with the design and installation of the Andco system such as concrete sump and foundation design, metric drawing requirements, outdoor installation modifications, structural steel design, etc. in order to provide you with a complete engineering package and a quality installation.

#### **Optional Service Contract**

Andco has a full staff of process engineers who have been thoroughly trained in the chemical, mechanical and electrical aspects of our system operations. As an additional service to our clients, we offer an annual service contract, which is designed to maintain system performance (and thereby reduce the risk of noncompliance), reinforce operator training and operator understanding of the system's operation, and overall preventive maintenance to avoid potential malfunctions. This service is routinely provided on a quarterly basis and charged on Time and Material plus expenses. An estimated cost for your operation would be provided upon request.

**Andco Heavy Metal Removal System**

September 15, 1992

Page 6

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**Price**

For the above described Andco Model "7F" Heavy Metal Removal System, we are pleased to quote a price, F.O.B. point of manufacture, of ..... \$1,700,000.

**Terms**

Our standard terms are thirty percent payment with order, an additional sixty percent payable when equipment is ready for shipment, and the balance of ten percent payable 30 days after shipment is made or at time of start-up, whichever is earlier.

Additional terms and conditions shown on the attached sheet E-203 are herein made a part of this proposal.

**Shipment**

Based on our production schedule, shipment will be made 16 to 18 weeks from date of receiving your order at Amherst, New York, and clearing of details. A formal project schedule will be prepared and submitted to you during the initial phase of the project.

**Start-Up Service**

Andco can provide start-up services for the electrochemical system. We can train your people during normal business hours in system operation and maintenance. The price for start-up and training assistance is \$575 per day plus travel and living expenses. Complete operating instructions will be provided for the system, as outlined above.

Sincerely,

**ANDCO ENVIRONMENTAL PROCESSES, INC.**

Jack I. Reich  
Sales Engineer

JIR/cs

**Appendix C**  
**Cost Estimate**

**Table C-1**  
**Ferrous Ion Reduction and Precipitation Package System**  
**Summary of Capital and O&M Costs**

Page 1 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Capital Costs</b>				
Major Purchased Equipment (MPE)				
Package Chromium Removal System <sup>a</sup> (Include: Reactor Module, Clarifier Module, Chemical Storage Tanks, Sludge Holding Tanks, Filterpress, Filtrate Sump Tank)	1	lot	686,000	686,000
Package Filters System (2000 gpm) <sup>a</sup>	1	lot	315,000	315,000
Air compressor and blower system	1	ea	10,000	10,000
Influent, Filter, and Effluent Pumps (2000 gpm, TDH=30', hp=20)	3	ea	7,000	21,000
Equalization Tank	1	ea	15,000	15,000
<b>Total MPE</b>				<b>1,050,000</b>
Installation Cost				
Piping, Concrete, Steel	22%	% of MPE		231,000
Electrical, I&C	12%	% of MPE		126,000
Installation Labor	25% <sup>b</sup>	% of MPE		263,000
<b>Total Installation Costs</b>				<b>620,000</b>
<b>Major Equipment Installed (MEIC)</b>				<b>1,670,000</b>
Site Preparation	10%	% of MEIC		167,000
<b>Total Field Cost (TFC)</b>				<b>1,840,000</b>
Fees and Contingencies				
Contingency	20%	% of TFC		368,000
<b>Subtotal</b>				<b>2,210,000</b>
Contractors OH&P	30%	% of Subtotal		663,000
<b>Total Capital Requirement</b>				<b>2,870,000</b>

**Table C-1**  
**Ferrous Ion Reduction and Precipitation Package System**  
**Summary of Capital and O&M Costs**

Page 2 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Operation and Maintenance Costs</b>				
Electricity		500,000 kwh/yr	0.14/kwh	70,000
Operating Labor		2,080 hr/yr	34/hr	71,000
Chemicals				
Ferrous Chloride (39%)		335 dry ton/yr	210/dry ton	70,000
Caustic Soda (25%)		250,000 lb/yr	.185/dry lb	46,000
Polymer (100% Neat)		4,750 lb/yr	2.50/lb	12,000
Sludge Disposal		2250 drums/yr	110/drum	248,000
Annual Maintenance	2%	% of Total Capital Requirement		57,000
<b>Total Annual O&amp;M Cost</b>				<b>574,000</b>
<b>Annualized Cost</b>				
<b>Total Capital Requirement (TCR)</b>				<b>2,870,000</b>
Interest Rate	10%			
Years	12			
Annualized Cost Factor	0.147			
Annualized TCR				422,000
<b>Total Annualized Cost</b>				<b>996,000</b>
<b>Present Worth</b>				
Present Worth Factor	6.81			
Present Worth O&M Costs				3,910,000
<b>Total Present Worth</b>				<b>6,780,000</b>

<sup>a</sup>Vendor provided information

<sup>b</sup>Lower installation labor due to skid-mounted equipment

**Table C-2**  
**Electrochemical Reduction and Precipitation Package System**  
**Summary of Capital and O&M Costs**

Page 1 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Capital Costs</b>				
Major Purchased Equipment (MPE)	1	lot	1,700,000	1,700,000
Package Chromium Removal System <sup>a</sup> (Include: Electrochemical Cell Module, Retention Tank, pH Adjust Tank, Polymer Feed system, Clarifier with built-in Thickening Tanks, Sludge Transferring Pumps, Filterpress, Multi-media Filter System, All Interconnecting Valve, Piping and Electrical.)				
<b>Total MPE</b>				<b>1,700,000</b>
Installation Cost				
Piping, Concrete, Steel	11% <sup>b</sup>	% of MPE		187,000
Electrical, I&C	6% <sup>b</sup>	% of MPE		102,000
Installation Labor	25%	% of MPE		425,000
<b>Total Installation Costs</b>				<b>714,000</b>
<b>Major Equipment Installed (MEIC)</b>				<b>2,410,000</b>
Site Preparation	10%	% of MEIC		241,000
<b>Total Field Cost (TFC)</b>				<b>2,650,000</b>
Fees and Contingencies				
Contingency	20%	% of TFC		530,000
<b>Subtotal</b>				<b>3,180,000</b>
Contractors OH&P	30%	% of Subtotal		954,000
<b>Total Capital Requirement</b>				<b>4,130,000</b>

**Table C-2**  
**Electrochemical Reduction and Precipitation Package System**  
**Summary of Capital and O&M Costs**

Page 2 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Operation and Maintenance Costs</b>				
Electricity		500,000 kwh/yr	\$0.14/kwh	70,000
Operating Labor		2,080 hr/yr	\$34/hr	71,000
Chemicals				
Caustic Soda (25%)		250,000 lb/yr	0.185/dry lb	46,000
Polymer (100% Neat)		4,750 lb/yr	2.50/lb	12,000
Steel Plate Electrode <sup>a</sup>		4 sets/yr	5,000/set	20,000
Sludge Disposal		2,250 drums/yr	110/drum	248,000
Annual Maintenance	2%	% of Total Capital Requirement		83,000
<b>Total Annual O&amp;M Cost</b>				<b>550,000</b>
<b>Annualized Cost</b>				
<b>Total Capital Requirement (TCR)</b>				<b>4,130,000</b>
Interest Rate	10%			
Years	12			
Annualized Cost Factor	0.147			
Annualized TCR				607,000
<b>Total Annualized Cost</b>				<b>1,160,000</b>
<b>Present Worth</b>				
Present Worth Factor	6.81			
Present Worth O&M Costs				3,750,000
<b>Total Present Worth</b>				<b>7,880,000</b>

<sup>a</sup>Vendor provided information

<sup>b</sup>Reduced percentage due to some materials included in the package system

**Table C-3**  
**Ion Exchange System**  
**Summary of Capital and O&M Costs**

Page 1 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Capital Costs</b>				
Major Purchased Equipment (MPE)				
Influent Pump (50 hp; 200 gpm; TDH=40 ft)	1	ea	15,000	15,000
Anion Exchange Column (10 ft diameter x 10 ft tall, each with 540 cubic feet of resin @\$325/ft <sup>3</sup> )	6	ea	399,000	2,390,000
Regenerant Storage Tank	4	ea	50,000	200,000
Brine System (brine holding tanks and pumps)	1	ea	216,000	216,000
Control Panel	1	ea	250,000	250,000
<b>Total MPE</b>				<b>3,070,000</b>
Installation Cost				
Piping, Concrete, Steel	22%	% of MPE		675,000
Electrical, I&C	12%	% of MPE		268,000
Installation Labor	25%	% of MPE		768,000
<b>Total Installation Costs</b>				<b>1,810,000</b>
<b>Major Equipment Installed (MEIC)</b>				<b>4,880,000</b>
Site Preparation	10%	% of MEIC		488,000
<b>Total Field Cost (TFC)</b>				<b>5,370,000</b>
Fees and Contingencies				
Contingency	20%	% of TFC		1,070,000
<b>Subtotal</b>				<b>6,440,000</b>
Contractors OH&P	30%	% of Subtotal		1,930,000
<b>Total Capital Requirement</b>				<b>8,370,000</b>



**Table C-3**  
**Ion Exchange System**  
**Summary of Capital and O&M Costs**

Page 2 of 2

Item/Description	Quantity	Unit	Unit Cost \$	Total Cost \$
<b>Operation and Maintenance Costs</b>				
Electricity		700,000 kwh/yr	0.14/kwh	98,000
Operating Labor		2,080 hr/yr	34/hr	71,000
Chemicals				
Caustic Soda		100,000 lb/yr	0.185/dry lb	19,000
Sulfuric Acid		110,000 lb/yr	0.04/lb	4,000
Resin Replacement		1,620 ft <sup>3</sup>	325/ft <sup>3</sup>	527,000
Brine Disposal <sup>a</sup>		36 load/yr	5,650/load	203,000
Annual Maintenance	2%	% of Total Capital Requirement		167,000
<b>Total Annual O&amp;M Cost</b>				<b>1,090,000</b>
<b>Annualized Cost</b>				
<b>Total Capital Requirement (TCR)</b>				<b>8,370,000</b>
Interest Rate	10%			
Years	12			
Annualized Cost Factor	0.147			
Annualized TCR				1,230,000
<b>Total Annualized Cost</b>				<b>2,320,000</b>
<b>Present Worth</b>				
Present Worth Factor	6.81			
Present Worth O&M Costs				7,420,000
<b>Total Present Worth</b>				<b>15,800,000</b>
<sup>a</sup> Vendor provided information				